A satellite solution

NASA and Japan's CRL have demonstrated the feasibility of telemedicine and distance learning over satellite. By **DC Palter**, vice-president of Mentat Inc.

A White House-honoured set of experiments between the US and Japan demonstrated that telemedicine, remote astronomy, and distance learning applications are all feasible over high-speed satellite links. However, this project also illustrated the immense organisational and technical challenges that must be overcome in creating a complex network spanning continents, organisations, and suppliers, especially when the network is built with volunteered time and donated equipment.

A joint effort of the US and Japanese governments with a network stretching across the US, Japan, and Canada, the Trans-Pacific Demonstrations (TPD) were the concluding experiment in the Global Infrastructure for Broadband Networks (GIBN) project. The TPD experiments were designed to illustrate the use of high-speed satellite links in combination with long distance terrestrial networks for next generation telemedicine, remote astronomy, and remote education use.

In the US, project coordination was the responsibility of the NASA Research and Education Network (NREN) organisation. Their counterpart in Japan was the Communications Research Laboratory (CRL), a national laboratory for info-communications research which focuses on next-generation networking and wireless technology.

Remote astronomy and telemedicine over satellite

The TPD experiments combined remote astronomy and telemedicine running over a single, hybrid satellite-terrestrial network. Explains Dick desJardins, project coordinator for NREN: "The overall goal of the project was to demonstrate the effectiveness of satellite communications. We looked for tests and applications which show why you would need high-speed satellites and we came up with remote astronomy and telemedicine. In particular, these were two applications left remaining to do from previous GIBN experiments."

The remote astronomy demonstration allowed students from around the world to view live images from an actual telescope. These experiments were designed to determine if satellite latency would interfere with student interactivity and to test videoconferencing applications and multicast tools for general distance learning usage.

Digital images from a camera attached to a telescope at the Mount Wilson Observatory outside Los Angeles, California were sent to a reflector server at NASA Ames Research Centre near San Francisco, California. Participants from anywhere in the world were able to connect to the server to view the images from the telescope.

The telemedicine demonstrations were designed to illustrate that the extremely large file sets required for medical applications can be moved effectively over high-speed satellites despite the technical limitations of the Internet protocols when used over high latency satellite links. In particular, these tests required a double satellite hop and took advantage of protocol gateway technology to overcome the TCP issues.

The telemedicine experiments connected researchers at the Sapporo Medical University, located on the northern Japanese island of Hokkaido, to the US National Library of Medicine in Bethesda, Maryland. The tests specifically focused on the transfer of Visual Human data, a library of digitised images showing cross-sections of the male and female human body from the National Library of Medicine for use in Japan (see figure 1).

Complex hybrid network

In order to move the data and images from the US to Japan, TPD built a highly complex, hybrid satellite-terrestrial network. With only a minimal budget, the project's primary challenge was the setup and operation of this network.

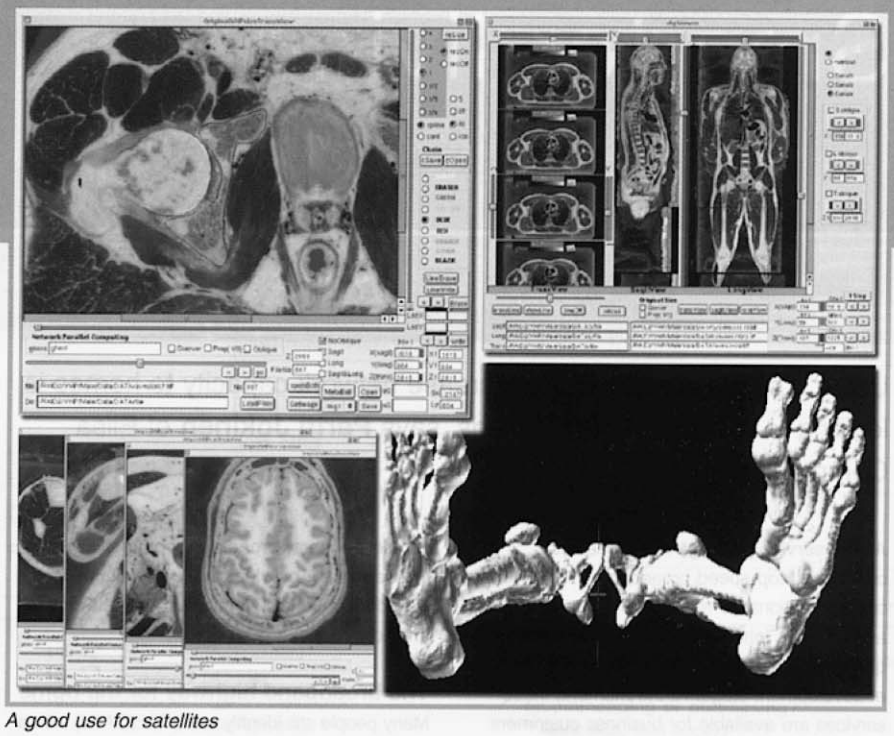
Figure 2 shows an illustration of the TPD network. Within the US, the high-speed terrestrial network operated by NREN connected NASA's Goddard Space Flight Centre, University of Maryland, and the National Library of Medicine, all located in the Washington, DC region, to the NASA Ames Research Centre, NASA Jet Propulsion Laboratory, and Mt Wilson Observatory in California. To reach Teleglobe's teleport in western Canada, the NREN network connected to the Canarie network at StarTap in Chicago, Illinois. The data travelled across Canada to the BC GigaPOP in Vancouver, British Columbia, and over AT&T Canada's network to the Lake Cowichan teleport.

An Intelsat 802 satellite link transported the data across the Pacific Ocean to the Kashima Space Research Centre near Tokyo, where a terrestrial link connected the teleport to CRL headquarters. A second satellite link, using a Ka-band transponder on the JSAT/NTT N-Star satellite, connected CRL to Sapporo Medical University, illustrating the use of Ka-band technology for high-speed data transfer.

The network also included a separate, parallel terrestrial link across the Pacific Ocean for comparison testing and back-up, an important consideration for mission critical links, but further complicating setup and troubleshooting. The terrestrial link showed a round-trip time of less than 200 minutes while the latency on the double satellite hop from Sapporo Medical University to the National Library of Medicine was measured at 1125 milliseconds.

With so many separate organisations involved in the demonstration, many of which were donating their time, equipment and services, project coordination was a Herculean task and by far the most difficult part of the project.

According to Pat Kaspar of NASA Ames: "The management problems were at least as great as the technical challenges for several reasons: the many organisations involved from government, industry, and academe, the language difficulties, the time zones, the small staff and limited budgets, and the mix of commercial and experimental network services." Explains NREN's desJardins: "Implementing a test network with parts that



A good use for satellites

were commercial and parts that were research within a production environment was much more difficult than anticipated."

In order to keep the effort on track, the team instituted weekly telephone conferences to discuss current status and assign work items. An e-mail mailing list and project web page was used for ongoing communications. However, the part-time participants with other urgent responsibilities often had difficulty keeping on top of the sheer volume of e-mail generated by the project during installation and troubleshooting. Combined with the turnover in support personnel from the commercial networks, keeping everyone up to speed while debugging the network was a constant battle.

Leaping technical hurdles

Despite painstaking planning, TPD hit two technical hurdles that for a time brought the completion of the project into doubt.

With time running out on use of the donated satellite transponders, the team still had not established basic connectivity over the satellite link. Network troubleshooting was complicated by time zone differences between North America and Japan and conflicting holiday schedules in Japan, Canada and the US.

With little time to spare, the source of the connectivity problem was finally tracked down. Because the satellite link was being shut down over weekends and holidays, the terrestrial carriers, used to handling production links, detected the unused line and set them into loopback mode. Restarting the satellite links also required resetting each of the terrestrial links. With so many different organisations involved in establishing the link, what in hindsight now seems obvious required weeks to track down.

Troubleshooting the network with participants scattered across the globe created heavy hardships, especially for the Japanese side. Says Naoto Kadowaki, project coordinator for Japan's CRL: "We had to stand-by almost all night while the North American colleagues were troubleshooting. Because we are a research organisation, not a carrier, we are not organised to handle 24-hour operations."

Meanwhile, the Visual Human implementation group discovered that the file viewer program was hitting the limitations of TCP/IP in transferring the large image files over the long delay link. Even over the parallel terrestrial network, throughput rates were measured at only 800kbit/s, and with the double satellite hop the throughput over the satellite link was limited to 224kbit/s or less.

Fortunately, NASA Goddard was already familiar with a solution which enhances the throughput of TCP over satellite links, which thereby jumped to 15.2Mbit/s.

Explains Kevin Kranacs of NASA Goddard: "The long satellite delay was a challenge. The telemedicine application used both TCP and UDP for communication. Some portions of the application were having difficulties with the one second delay."

Eventual success

The process of setting up the network and resolving the TCP issues consumed most of the time budgeted for the project, leaving the group little time for the demonstrations themselves. Fortunately, a final push including more weekend and holiday hours allowed the team to complete the demonstration.

Students at Soka High School in Tokyo were able to view images from the Mt Wilson Observatory telescopes in real time. Other participants at Crossroads High School, University of Maryland, and NASA's Jet Propulsion Laboratory were able to log onto the telescope server and videoconferencing system to discuss the images with each other and observe each other's activities.

According to desJardins, "Overall, the fun part of this project was getting the data flowing over a double satellite hop and pushing the throughput to near the theoretical maximum. But the most important result was showing excellent hybrid communications between two types of terrestrial networks and demonstrating that terrestrial and satellite networks can co-exist for mutual benefit."

In Japan, according to Haruyuki Tatsumi, who is project director at Sapporo Medical University, they are now "taking advantage of the fruits of the project by using telemedicine in Hokkaido." In particular, the redundancy aspect of the dual hybrid-satellite network allowed them to demonstrate that when "we disconnect the line, another terrestrial route becomes alive in a minute. That kind of thing is very important for end users and medical use."

Afterwards, NASA received a letter of congratulations from Thomas Kalil, Deputy Director of the White House National Economic Council, who wrote, "The trans-Pacific experiments demonstrated in an impressive fashion that high quality, high data rate, interactive communications may be obtained over a complex network of multiple satellite and fibre optic links. The experiments also evidenced a significant level of national and international cooperation, involving government-industry teams from three countries - Japan, Canada, and the US. I believe the series of trans-Pacific experiments which NASA has conducted has contributed a great deal to the development of advanced satellite communications technology and paved the way for extensive use of satellites in the Internet of the future." <end>

Mentat is a supplier of networking protocols and TCP/IP over satellite performance-enhancement technology.